

Magnetic dipole moment of the Xe $4d^{-1}$, Kr $3d^{-1}$ and Ar $2p^{-1}$ hole states - first measurements with the EPU at beamline 4.0

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INTRODUCTION

The atomic or molecular photoionization process usually leaves the singly charged photoion in a polarized state, i.e. with an uneven population of the magnetic sublevels. In the case of inner-shell photoionization the photoion can relax through a radiationless decay process by emitting Auger electrons. The decay of a polarized photoion may lead to an anisotropic angular distribution and also to spin polarization of Auger electrons.

In the two-step model of Auger decay, where the photoionization and Auger decay processes are assumed to proceed subsequently and independently of each other, the angular anisotropy parameter and the spin polarization parameters of the Auger electron can be factorized into a parameter describing the anisotropy of the primary hole state and into an ‘intrinsic’ parameter describing the Auger decay itself. With known values of the intrinsic parameters the alignment A_{20} and the orientation A_{10} of the primary hole state can be determined from the angular distribution and the spin polarization of Auger electrons, respectively. Alignment and orientation are proportional to the electric quadrupole moment and magnetic dipole moment of the photoion and are directly connected to the amplitudes of the dipole matrix elements. While alignment can be created by any kind of particle or photon impact, orientation requires excitation by polarized particle impact or by circularly polarized photons.

The description of the photoionization process in the framework of the dipole approximation limits the possible values of the orbital angular momenta of the outgoing photoelectrons according to the selection rules. In the case of a d-ionization for example, the electrons can leave the atom as ϵp or ϵf continuum waves. In the nonrelativistic approximation there is no further spin-orbit splitting of these waves in the continuum. The alignment and orientation tensors of the hole state depend only on the ratio of the dipole amplitudes [1].

EXPERIMENT

We performed spin polarization measurements of the Xe $N_{4,5}O_{2,3}$, Kr $M_{4,5}N_{2,3}$ and Ar $L_{2,3}M_{2,3}$ Auger electrons with circularly polarized light from threshold up to 540 eV photon energy. These measurements [2] were carried out at the new Elliptical Polarization Undulator (EPU) beamline (BL 4.0.2) of the Advanced Light Source. Since for Auger electron spectroscopy no high photon resolution is needed, we could utilize the unmonochromatized beam of the fundamental of the undulator, which resulted in a bandwidth of $\approx 3\%$. The photon flux behind a focusing mirror was estimated to be 10^{16} photons/(s·100 mA) in the full undulator fundamental. An additional benefit was that in the circular polarization mode, the EPU produces no higher harmonics, thereby avoiding the need for filters. The spin-resolved electron spectra were recorded by a new spectrometer system consisting of a time-of-flight (TOF) electron energy analyzer combined with a retarding field Mott polarimeter [3,4]. This instrument allows very effective data acquisition, because all electron lines in the TOF spectrum are spin-analyzed simultaneously

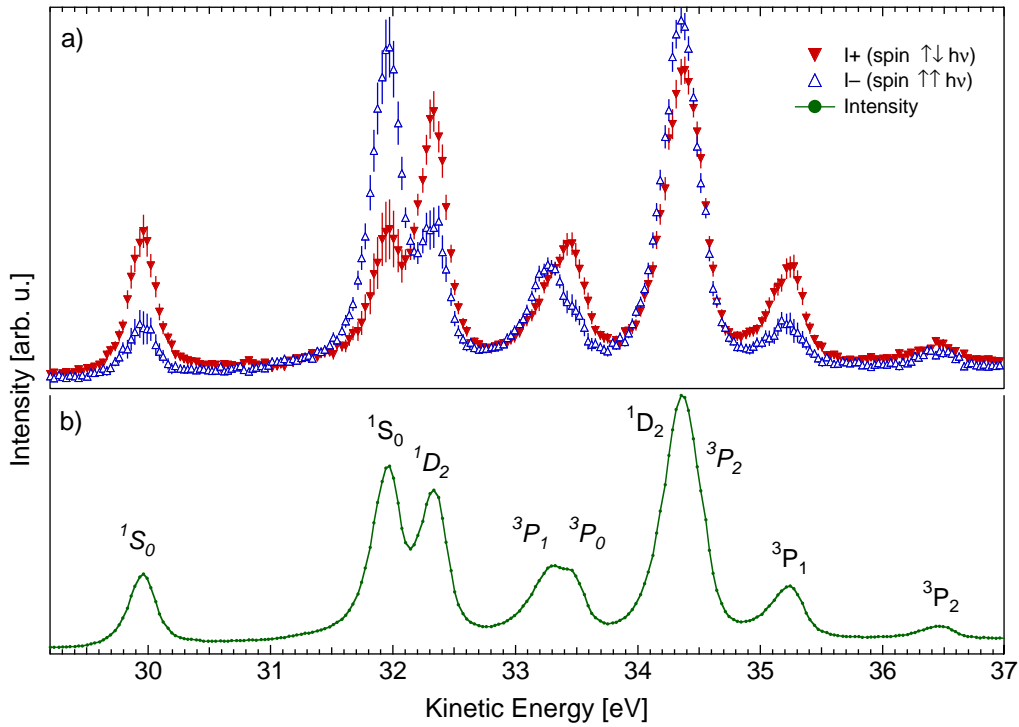


Figure 1. Spin-resolved Xe $N_{4,5}O_{2,3}O_{2,3}$ Auger spectra recorded at 127 eV photon energy with circularly polarized radiation. The photon bandpass was approx. 3.5 eV. a) spin-resolved intensity; b) total intensity. The annotations in italic denote the N_5 initial hole states.

with a high signal to noise ratio. The electron spin polarization component parallel to the photon beam at an emission angle of 90° with respect to the light beam was measured. A spin-resolved Xe $N_{4,5}O_{2,3}O_{2,3}$ Auger spectra is shown in Fig. 1.

RESULTS

Using 1S_0 -Auger lines, for which the intrinsic parameters are fixed geometrical factors, we could derive the orientation A_{10} of the Xe $4d^{-1}$, Kr $3d^{-1}$ and Ar $2p^{-1}$ hole states over a broad photon energy range. Fig. 2 shows A_{10} of the Xe $4d^{-1}$ hole state as a result of a preliminary analysis. A_{10} shows a strong variation and reaches its extreme values (marked by stars in Fig. 2) at threshold, in the maximum of the shape resonance (~ 100 eV) and in the Cooper-minimum (~ 175 eV) of the photoionization cross section. These extreme values indicate directly the strong f character of the continuum electrons in the shape resonance and the vanishing of the f partial wave at threshold (because of the centrifugal barrier for the f electrons) and in the Cooper-minimum (where the f dipole amplitude crosses zero). This is a direct experimental proof that in the Cooper-minimum of a d-subshell photoionization the outgoing electrons have a purely p character.

Agreement with previous experimental data [5,6] is good. The overall shape of the theoretical curve [7], a nonrelativistic, frozen-core random-phase approximation calculation, is similar to the experimental data, giving the position of the maximum at somewhat lower energy than the experiment. The dashed curve in Fig. 2 was obtained by stretching the RPAE curve to higher energies, to match the maximum in the experimental data. This curve gives a very good agreement with our results.

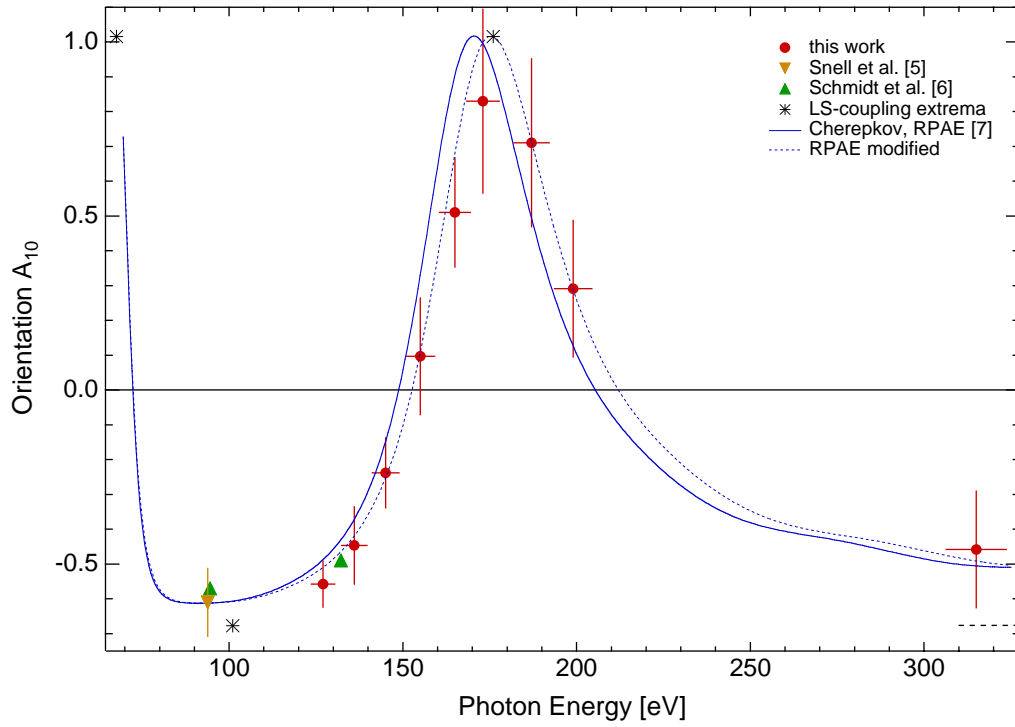


Figure 2. Orientation A_{10} of the Xe $4d^{-1}$ hole state. The stars show the extreme values of A_{10} in LS-coupling for a vanishing f-wave (at threshold and in the Cooper minimum) and vanishing p-wave in the cross section maximum (see also text). The dashed curve was obtained by stretching the theoretical RPAE curve.

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